



On the utility of experiential cross-training for team decision-making under time stress

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This study investigated the effectiveness of *experiential cross-training in a team context* for team decision-making under time stress in a simulated naval surveillance task. It was hypothesized that teams whose members explicitly experience all team positions will perform better under time pressure due to a better shared Team Interaction Model (Cannon-Bowers *et al.* 1993). In addition, it was posited that experiential cross-training would reduce the negative effect of member reconfiguration that can occur in certain military situations. Three groups of teams participated in this study (cross-trained, reconfigured and control). The experiment involved three team training sessions, followed by three time-stressed exercise sessions. During training, one group of teams was cross-trained (CT) by asking each member to perform an entire session at each of the three team positions. Member reconfiguration (where each member was shifted to another's position) was unexpectedly introduced at the first of the exercise sessions for the CT group and for another group (reconfigured) that had not been cross-trained. A third (control) group was neither cross-trained nor reconfigured. During training, the performance of non-CT teams improved more quickly than that of CT teams. During the exercise, the CT group did not achieve the level of performance of the control teams. The immediate effect of team member reconfiguration was to degrade performance significantly for the non-CT teams, but not for the CT teams. The findings are discussed in terms of the multiple mental models' view of team performance (Cannon-Bowers *et al.* 1993) and the authors discuss the relative utility of cross-training when overall training time is fixed.

1. Introduction

Military missions often demand that teams of personnel tackle ill-defined problems in the face of dynamic environments and uncertain information. In addition, military taskings can have critical time constraints, can involve high stakes, and must often be accomplished under conditions of mental fatigue, high workload, threat of physical injury and in hostile environments (e.g. poor terrain and weather). The number and magnitude of these constraints can conspire to undermine interpersonal communication and co-ordination and they underscore the importance of effective teamwork. The issues associated with teamwork are reflected in a growing body of empirical work on team communication (Lassiter *et al.* 1990, Urban *et al.* 1995), team

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training (Cannon-Bowers *et al.* 1995), shared mental models (Cannon-Bowers *et al.* 1993), methods for measuring teamwork (Fowlkes *et al.* 1994, Brannick *et al.* 1995, Baker and Salas 1997) and models of team development (Morgan *et al.* 1994). Many of these same concerns motivate the research on crew resource management and overall aircrew proficiency (Foushee *et al.* 1986, Kanki *et al.* 1989, Kanki and Palmer 1993, Orasanu 1993). Beyond the issues driving this body of empirical literature, one need only recall the tragic results of the *USS Vincennes* incident when the crew shot down an Iranian airliner after misinterpreting data from electronic sensors (Orasanu and Salas 1993), or any number of air crashes, to acknowledge the necessity of highly trained and well co-ordinated teams in many military environments.

Despite the critical importance of teams and teamwork, the issue of *how* to most effectively train teams is only emerging now as a focus of research interest (Salas *et al.* 1997). Indeed, several theorists have hypothesized that effective team performance is a function of the presence and timely accessing of multiple mental models associated with a given task (Rouse and Morris 1986, Cannon-Bowers *et al.* 1993). A mental model is defined by Thompson *et al.* (1997: 971) as:

the knowledge necessary to perform a task and may encompass past, present, and future [task] parameters, goals, and considerations. Well-developed mental models are assumed to lead to more efficient information processing, to decreased time pressure and workload, and to better performance.

In fact, according to Cannon-Bowers *et al.* (1993), team performance in situations of high complexity seems to require multiple shared mental models including the following.

- (1) *Equipment Model*—knowledge of the equipment functioning and operation.
- (2) *Task Model*—procedures, contingencies, strategies, and constraints.
- (3) *Team Interaction Model*—roles, responsibilities, information sources, communication channels and role interdependencies.
- (4) *Team Model*—assessments of teammates' knowledge, skills, abilities and tendencies.

One specific training method assumed to enhance team-related mental models—and thus performance—is termed *cross-training*. Volpe, Cannon-Bowers, Salas and Spector (1996: 87) assert that:

Cross training refers to a strategy in which each team member is trained on the tasks, duties and responsibilities of his or her fellow team members. The goal of this type of training is to provide team members with a clear understanding of the entire team function and how one's particular tasks and responsibilities interrelate with those of the other team members.

Thus, the common or shared mental models resulting from cross-training are thought to allow team members to (1) anticipate the sorts of information and assistance that fellow team members might require, (2) increase co-ordination, and (3) reduce the need for communication among teams. To date three empirical studies have demonstrated the utility of cross-training for improving team performance (Volpe *et al.* 1996, Schaafstal and Bots 1997, Cannon-Bowers *et al.* 1998).

Volpe *et al.* (1996) studied two-person teams flying a simulated F-16 aircraft mission to locate and shoot down enemy aircraft. It was hypothesized that cross-training would have a positive effect upon communication pattern and frequency, thus improving task performance. Cross-training was manipulated by providing an instructional booklet and an audiotape explaining the requirements of the two team positions (cross-training condition) or the trainee's own position (no cross-training condition). Cross-trained teams volunteered information more often than did non-cross-trained teams, and they demonstrated better task performance (e.g. locking-on and shooting down enemy targets significantly more often) than did non-cross-trained teams.

More recently, Schaafstal and Bots (1997) investigated the effect of different methods of cross-training on team performance and communication under high and low time pressure using a team TACTical Naval DECision Making task (TANDEM; for a recent review of TANDEM and its applications in team research, see Kozlowski and Gully 1996). In their TANDEM task, three-person teams of naval recruits had to share information to make decisions concerning the type, class and intent of radar-based contacts, and then decide whether to 'shoot' or 'clear' these contacts. Three cross-training methods were compared: (1) 'reading only' where each team member read a written synopsis of the tasks and roles of the other team members; (2) 'reading and practice' where team members were given both written synopses and short (15 min) individual practice sessions on the tasks of the other two team members; and (3) 'explicit instruction' where an explicit written description was given on the overlap between the different tasks of the team members. Performance was then measured in three experimental sessions under low time pressure, followed by three sessions under high time pressure.

There was no difference in performance or communication between the 'reading only' and 'reading with practice' cross-training methods. However, teams cross-trained using explicit information on the overlap between tasks of the members were significantly better on all TANDEM performance measures (e.g. higher total score and number of tracks correctly identified; fewer penalty points) than teams trained in either of the other cross-training methods. Furthermore the 'explicit instruction' teams used fewer question/answer communication exchanges; instead, team members proactively offered information to other members, even though this information had not been explicitly requested.

Building upon the work of Volpe *et al.* (1996), Cannon-Bowers *et al.* (1998) also used the TANDEM task to investigate the effect of cross-training (presence vs. absence) upon team process and team performance. In this case, cross-training consisted of interpositional rotation in which each team member was trained on and rotated through the tasks at each of the three team member stations. TANDEM is a highly interdependent team task and therefore Cannon-Bowers *et al.* (1998: 94) argued that cross-training by a positional rotation strategy is necessary since 'team members require extensive knowledge of their team mates' roles and tasks so that they can anticipate the information needs of team mates and co-ordinate their activities'. It was hypothesized that cross-training would increase overall task performance (e.g. TANDEM team score, the number of contacts that were shot or cleared correctly) and teamwork (as measured by raters' estimates and various indices of communication). Results showed clear support for these hypotheses, particularly under conditions of high workload.

In summary, three studies to date have documented the utility of cross-training as a method for improving team performance. As previously mentioned, cross-training is thought to foster the development of shared mental models (Cannon-Bowers *et al.* 1993), particularly the Team Interaction Model (i.e. interaction patterns, communication channels, role interdependencies). Consequently, the potential benefits of cross-training can be seen from at least two points of view for the military application. First, the utility of cross-training should be particularly noticeable under conditions of high time pressure, as such circumstances have the greatest demands for co-ordination amongst team members with the least possibility for communication. Second, cross-training could have the additional benefit of preparing team members for the possibility of the team being reconfigured due to injury, turnover in personnel or the loss of a team member.

In the present study, the authors seek to extend the positional rotation cross-training methodology of Cannon-Bowers *et al.* (1998) with a view to enhancing the development of the Team Interaction Model described by Cannon-Bowers *et al.* (1993). Previous studies have investigated only individual cross-training—i.e. team members were not trained while performing the task as a team. It is posited, however, that some of the knowledge in the Team Interaction Model, especially that concerning the dynamics of the team task, can be acquired only by actually experiencing the task in the team context. We hypothesize, therefore, that an augmented degree of cross-training, which we term *experiential cross-training in a team context*, is desirable in order for members to fully appreciate role interdependencies and team interaction patterns, as well as other team members' skills and abilities that contribute to the Team Model.

Hypothesis 1: Relative to a control group, teams that have undergone team-level experiential cross-training will display better performance in a simulated military exercise involving high time pressure.

Additionally, it is posited that experiential cross-training may ameliorate the antagonistic performance effects of member reconfiguration on team members. To date, the issue of member reconfiguration has not been studied, and thus the present study provides both an examination of its effect on team performance and a test of the hypothesis that experiential cross-training can be effective in such situations.

Hypothesis 2: Team level experiential cross-training reduces the negative effect of member reconfiguration on team performance.

2. Method

2.1. Subjects

Participants were 90 employees of the Canadian Department of National Defence. Thirty-three participants were Regular Force, 54 were Reservists, and three were civilian students used to complete a team when a military member was unexpectedly unable to participate.

2.2. Apparatus

Three PC workstations were used to present the task and collect data. The workstations were arranged in a triangular fashion, facing each other, in the centre of a large room. Workstations were monitored from a separate control room

through four video cameras, three aimed at the subjects' screens and one providing an overview of the entire work area. A version of TANDEM, which had been developed at the University of Central Florida under the US Navy TADMUS project, was used as the task. Team members wore headsets so that their verbal communications could be recorded on separate channels of a 4-channel tape recorder.

2.3. Task

TANDEM is a medium fidelity simulation of a naval shipboard surveillance task designed for studying team performance. Subjects are presented with a radar-like screen on which contacts (symbolized by asterisks) are shown surrounding a symbol representing own-ship. The contacts represent surface, sub-surface and air traffic that has been identified by the ship's radar system. Each contact must be processed based on information available from drop-down menus. Processing a contact requires that a classification be made in three categories: type, class and intent (determined by team members Alpha, Bravo and Charlie, respectively). The type category concerns whether a contact is air, surface or subsurface; class concerns whether it is civilian or military; and intent whether the contact is peaceful or hostile. Classifications in all three categories are required before Charlie makes the final decision to shoot or clear. Once processed, the contact disappears from the screen and feedback is given to the team on whether the classifications and the final decision were correct. In addition, there is a running score for the task that is shown numerically in the top corner of the screen. A clock in the corner of the screen shows the elapsed time since the start of the session.

The TANDEM menus for Alpha, Bravo and Charlie provided three of the five information elements pertaining to their own classification task (i.e. type, class and intent, respectively), and two information elements pertaining to the tasks of the other team members (one for each of the other team members). This distribution of information forced subjects to function as an interdependent team, since the values of two of the information elements needed for a classification by any team member had to be obtained verbally from other team members.

2.4. Design

The experiment employed a 3 between (Cross-trained vs. Reconfigured vs. Control) $\times$ 2 within (Training and Exercise) $\times$ 3 within (3 Sessions) design. Subjects participated in three-person teams that were randomly assigned to the cross-trained (10 teams), reconfigured (11 teams) or control (9 teams) groups upon arrival at the laboratory. Originally 11 teams were run in each condition. However, the data for two teams were excluded because their performance did not meet the accuracy criterion; the data for one team were lost because of a computer network malfunction. Teams completed three training sessions followed by three exercise sessions. All sessions involved processing 36 contacts. Teams gained 100 points for each contact correctly assessed, and lost 100 points for a contact incorrectly assessed. In addition, teams were penalized for contacts that remained within a 10-mile radius of own-ship (i.e. a cross-hatched area around the ship), designated as a 'danger zone'. The training sessions required that subjects learn to work as a team in order to achieve and maintain a high level of accuracy in the task (a score of 2800 out of a possible 3600, set in pilot testing). There was no time limit during the training sessions; however, teams were encouraged to progressively improve their contact

processing times over sessions (feedback was provided on accuracy and time after each session). In contrast to the training sessions, the exercise sessions were designed to induce time pressure through a scenario requiring that all contacts be processed within a set time limit (i.e. 18 min, a criterion established as being difficult, but possible, through pilot testing).

Teams in the cross-trained condition were rotated through one position at each training session (i.e. Alpha to Bravo, Bravo to Charlie, and Charlie to Alpha), reconfigured back to their original positions for the first exercise session, and then remained at those positions for two remaining exercise sessions (figure 1). Team members in the reconfigured condition stayed in their assigned positions for the three training sessions and then were unexpectedly reconfigured at the first exercise session. They then remained in those new positions for the remaining exercise sessions. Team members in the control condition remained in the same position throughout the study.

2.5. Procedure

Upon arrival at the laboratory (08:00 h) teams were briefed on the experiment, signed consent forms, and filled out questionnaires concerning demographics, personality, cognitive and group style. These data will not be discussed further in this paper.

As shown in figure 1, the study had three phases: familiarization, training and exercise. Familiarization began by teams receiving instructions as a group on a single-user version of TANDEM to acquaint them with the general features of the task and its interface. Two short practice sessions followed in which subjects individually performed the single-user task intended to familiarize each team member with all three TANDEM roles. An experimenter was available during this

Phase							
Familiarization		Training			Exercise		
Session							
		T1	T2	T3	E1	E2	E3
Cross-trained Group	Instruction+ all-position practice	Randomly assigned to A,B,C	Cross-training A->B B->C C->A	Cross-training A->B B->C C->A	Team members reconfigured A->B B->C C->A	No change in position	No change in position
Recon-figured Group	Instruction+ all-position practice	Randomly assigned to A,B,C	No change in position	No change in position	Team members reconfigured A->B B->C C->A	No change in position	No change in position
Control Group	Instruction+ all-position practice	Randomly assigned to A,B,C	No change in position	No change in position	No change in position	No change in position	No change in position

Figure 1. Design of the experiment

time to answer questions. The practice sessions lasted 20 min, or until the subject had completed 12 contacts, whichever occurred first. After a short break, teams were given additional instruction concerning the team version of the TANDEM task. The team task was explained with the aid of a diagram showing the information elements available at each workstation (Alpha, Bravo and Charlie). The team was told that Alpha's responsibility was to determine type, Bravo's to determine class, and Charlie's to determine intent. It was stressed that some of the information needed for a particular category classification was not available at the pertinent workstation and that team members would need to communicate information to each other. Thus, it is important to note that the familiarization training provided to all teams in the present study was similar to the cross-training employed in previous research. The training (three sessions) and exercise phases (also three sessions) of the study followed immediately after the familiarization phase.

Before each of the training and exercise sessions, the team was given 5 min to discuss their strategy for optimizing their performance on the task. These discussions were videotaped for later analysis. Following the 5 min strategy session, the team moved to the experimental room and positioned themselves at their assigned workstations. The team members remained at their workstations until all 36 contacts were processed. At the end of the session, the team was given feedback on its performance (session duration and accuracy) in the form of a graph showing performance over the sessions completed so far. The performance criterion score of 2800 was reiterated, as well as the need to process contacts as quickly as possible. The teams then proceeded directly into the 5-min strategy discussion for the next session.

Following the three training sessions, the subjects were given a lunch break. The format of the three afternoon sessions (the exercise condition) was identical to that of the morning sessions with the following differences designed to induce time pressure. Teams were instructed that they were now being exercised according to a scenario in which their ship was part of a larger naval task force patrolling a politically volatile area with heavy traffic and hostile threats. An offensive to counter an expected enemy attack was to be launched and all traffic surrounding the ship needed to be accounted for by the surveillance team within an allotted period of time. The team was given 5 min to discuss any new strategies for improving performance, after which an alarm sounded, signalling that the exercise had begun. The team quickly moved to the experimental room and was given 18 min (from the sound of the alarm) to accomplish their task. (Note however, that teams were required to complete all 36 contacts even if the 18-min time period was exceeded.) A large digital countdown clock projected on the wall near the team was used to induce time pressure. When the clock had counted down to 12 min, the digital numbers turned yellow and a recorded message was delivered over the subjects' headphones 'yellow alert, yellow alert, 12 minutes to counter offensive'. A similar message was delivered at 6 min signalling a red alert.

Prior to the first exercise strategy session, team members in the cross-trained and reconfigured conditions were assigned new positions: members were shifted one position (Alpha to Bravo, etc.), where they then stayed for the remainder of the exercise sessions. Teams members in the control condition were not reconfigured.

2.6. Measures

The overall aim of each team in TANDEM was two-fold. First, it was to train as a team to achieve as high a level of speed as possible, and then to attempt to achieve

the military exercise criteria of all contacts accurately processed within the allocated period of 18 min. Second, teams were instructed to maintain an accuracy of a score of at least 2800 out of a possible 3600 (i.e. 32/36 contacts correctly classified, or 89%). Thus, the 'outcome' measures for this task were set as time to process a contact, and score.

The overall task involved the accessing of menu items for information about each contact, the exchange of information about contacts among team members, as well as the assessment of type, class and intent, and final engagement on the basis of the contact information. In addition, teams were aware that they should minimize the amount of time that any unassessed contact was in the danger zone around ownship, since contacts in this area could, if hostile, be a particular threat to the ship. These 'process' activities in the TANDEM task were reflected in the following measures, collected directly by the TANDEM software: total duration of menu queries per contact, number of menu queries per contact and total time of contacts in danger zone.

The number of verbal utterances made by team members during task execution is considered to be indicative of the need for explicit co-ordination and thus a lack of a shared mental model (Cannon-Bowers *et al.* 1998). The verbal communications at each of the three team members' workstations were recorded and subsequently analysed using customized software (a full description of which is available from the authors) to count the number and duration of utterances at each position. For one of the reconfigured teams, communication data were lost due to a recorder malfunction.

Finally, the videotaped data from the 5-min strategy sessions (which occurred before each experimental session) were a source of information on processes that teams adopted for improving performance. They were analysed for verbal content as follows. The verbalizations made by all team members for four teams randomly chosen from each condition (12 teams in total) were transcribed into text. Each statement was then coded according to the categorization scheme given in the appendix. Approximately 1200 statements were made during the 72 strategy sessions that were analysed (3 groups $\times$ 4 teams $\times$ 6 sessions).

3. Results

The analysis will treat the design as a mixed factorial; i.e. 3 between (Team Assignment: Cross-trained vs. Reconfigured vs. Control) by 2 within (Training vs. Exercise) by 3 within (Session: 1, 2, 3). Note that two of the groups were treated differently on the first session of the exercise: the cross-trained and reconfigured groups were shifted one position to simulate reconfiguration, whereas the control group was not. Thus any main effects and interactions of training/exercise were qualified by *a priori* contrasts concerning that manipulation.

3.1. Outcome measures

3.1.1. *Time to process a contact:* An analysis of variance (ANOVA) on the mean time taken by teams to process a contact yielded significant main effects and interactions involving the team assignment factor. Figure 2(a) provides a plot of the findings. As expected, the time to process a contact is the same for all groups at the first training session (T1). Duncan *post hoc* comparison indicated that the time per contact dropped significantly for all groups between sessions T1 and T2 ($p < 0.001$). Performance for the cross-trained group then levelled off at session T3, whereas

performance for the reconfigured and control groups continued to improve ($p < 0.05$). Consequently there was a significant difference between these two groups and the cross-trained group at session T3 ($p < 0.0001$).

In the first exercise session (E1), the time per contact for the reconfigured group increased significantly ($p < 0.0001$). On the other hand, the time per contact for the

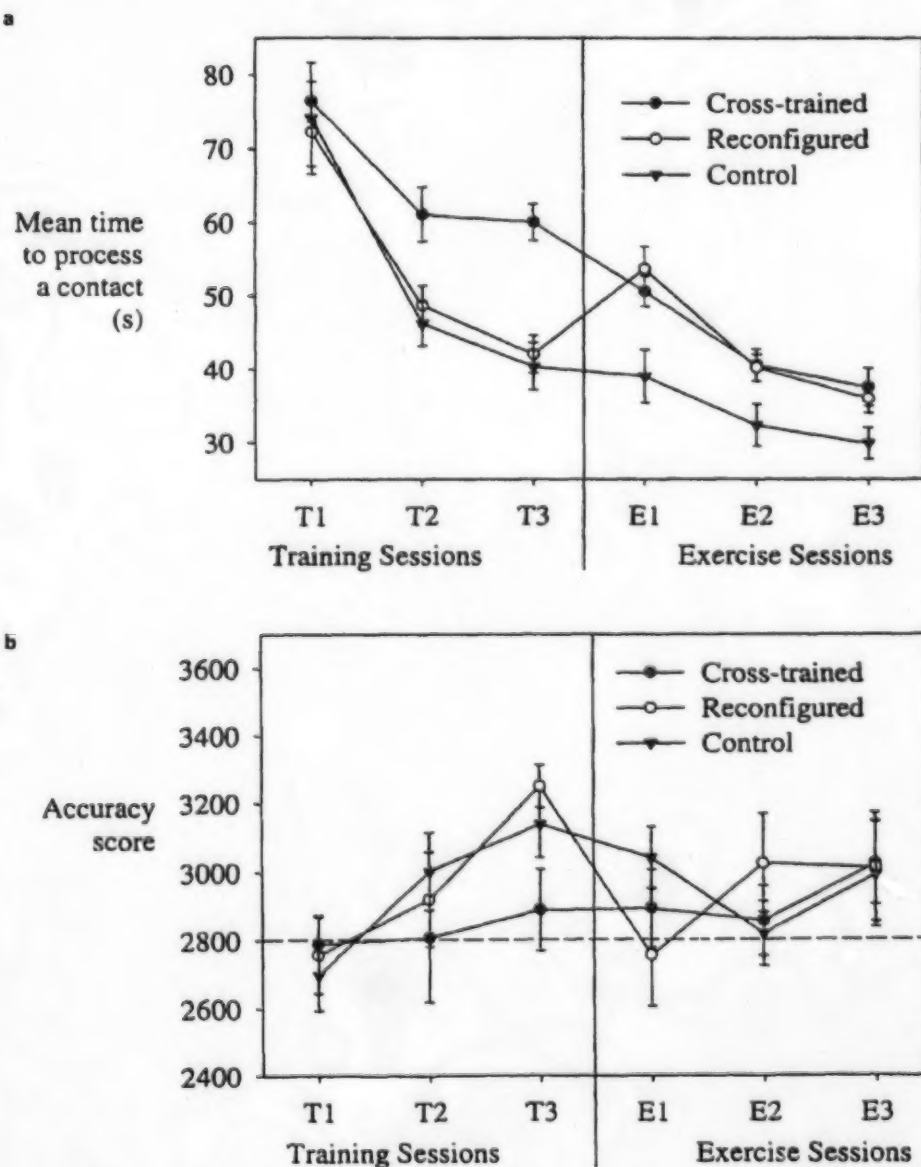


Figure 2. Outcome measures: (a) mean time to process a contact, (b) mean TANDEM score. Accuracy criterion is denoted by the dotted line.

cross-trained group decreased significantly from T3 to E1 ($p < 0.001$), although there was no difference between these two groups at session E1. The control group's performance did not improve between sessions T3 and E1, but it was still significantly better than either of the other groups ($p < 0.0001$). Time to process a contact decreased significantly for all groups between sessions E1 and E2 ($p < 0.01$), but there was no further change between E2 and E3. By E3, however, the control group's performance was still significantly better than that of the cross-trained group or the reconfigured group ($p < 0.05$).

3.1.2. Accuracy: Overall, teams were successful in achieving the accuracy criterion (score = 2800) that was demanded (figure 2(b)). An ANOVA of accuracy scores yielded only a main effect for session ($F(2,54) = 7.63$, $p < 0.01$). There were no significant interactions. *Post hoc* comparison showed that accuracy improved significantly for the reconfigured and control groups between sessions T1 and T3 ($p < 0.05$). However, it did not improve for the cross-trained group.

Accuracy decreased significantly for the reconfigured teams when they experienced the shift at E1 ($p = 0.02$); the mean score of these teams dropped from a high of 3250 at T3 to a low of 2750, just under the criterion level. There was no change in accuracy for either the cross-trained or control groups between T3 and E1. There was no further change for any group in the remaining sessions of the exercise.

3.1.3. Summary of outcome measures: In terms of the outcome measures of team performance (i.e. time to process contacts and accuracy) the following observations can be made: (1) during training, cross-trained teams displayed slower speed and lower accuracy compared to non-cross-trained teams; (2) the reconfigured teams (that had not been cross-trained) displayed an immediate and substantial performance decline at E1; however, at E1 their performance was *not poorer* than that observed for the cross-trained group; and (3) neither the cross-trained nor the reconfigured groups achieved the processing speed ultimately attained by the control group.

3.2. Process measures

3.2.1. Total duration of menu queries: The overall pattern of results for the mean total duration of menu queries is similar to that reported for the time to process a contact shown in Figure 2(a). Of note, at T3 the menu query time was significantly higher for the cross-trained group than for the other two groups. Query times increased from T3 to E1 for the reconfigured group ($p < 0.01$) but decreased for the cross-trained group ($p < 0.01$). The difference between these groups was not significant at E1, but both took significantly longer than the control ($p < 0.01$). By E3, however, there were no significant differences among the groups.

3.2.2. Number of menu queries per contact: The ANOVA for number of menu queries made by teams to retrieve information on each contact yielded a main effect for time stress ($F(1,27) = 31.60$, $p < 0.0001$), with teams making a mean of 18.4 queries per contact during training versus 16.6 during the exercise. There was also a significant main effect for session ($F(2,54) = 30.99$, $p < 0.0001$), confirming that the number of queries decreased across both training and exercise session. No other significant main effects or interactions were obtained.

3.2.3. Total time of contacts in danger zone: An ANOVA performed on the total time that any contact was present in the danger zone yielded significant main effects of time stress ($F(1,27) = 40.69, p < 0.0001$) and session ($F(2,54) = 14.66, p < 0.0001$) as well as an interaction between the two ($F(2,54) = 16.47, p < 0.0001$). As shown in figure 3(a), the time that contacts were in the danger zone dropped substantially ($p < 0.01$) from session T1 to session T3 for all groups. The danger zone time rose slightly but not significantly for the reconfigured group when they experienced shift in position at E1. Overall, at E1, the reconfigured group was slower than the other groups to respond to contacts in the danger zone; these differences approached but did not attain statistical significance. There were no subsequent differences between any groups at sessions E2 or E3.

3.2.4. Number of utterances per contact: The mean of the total number of verbal utterances made by team members per contact ranged from 35 in session T1 to 16 in E3. The actual number of utterances were Z-score transformed to normalize initial differences between groups. These data are illustrated in figure 3(b). ANOVA yielded a main effect for time stress ($F(1,26) = 107.81, p < 0.0001$) and for session ($F(2,52) = 139.17, p < 0.0001$). There was also a Time Stress $\times$ Session interaction ($F(2,52) = 29.94, p < 0.0001$) and a Team Assignment $\times$ Time Stress interaction ($F(2,26) = 5.49, p = 0.01$). The mean number of team utterances per contact dropped significantly from training session T1 to session T2 ($p < 0.001$ in all cases) and then levelled off at session T3. As was the case with time to process a contact, the combined effect of the time stress and the shift in position at exercise session E1 resulted in a significant rise in the number of utterances for the reconfigured teams ($p = 0.012$) from 17.3 to 22.5 utterances per contact. However, there was no change in the number of utterances between T3 and E1 for the other two groups. Teams in all groups continued to reduce their utterances during the exercise, so that by the final session, E3, the mean rate for all teams was significantly lower ($p < 0.05$) than at E1.

3.2.5. Statements in strategy sessions: Out of all statement categories, only those statements classified as 'clarification' (CLAR, see appendix; 297 in total) yielded significant effects. Figure 3(c) shows how the clarification statements were distributed across conditions. An ANOVA yielded a significant main effect of session ($F(2,18) = 30.53, p < 0.0001$). Two of the two-way interactions were significant: Team Assignment $\times$ Session ($F(4,18) = 3.25, p < 0.05$); and Time Stress $\times$ Session ($F(2,18) = 4.89, p < 0.05$). The three-way interaction was also significant ($F(4,18) = 11.98, p < 0.0001$). With one exception, the number of clarification statements dropped gradually across sessions for both training and exercise, from an initial mean of 6.8 statements per strategy session at T1 to 0.6 statements per session at E3. However the number of clarifications rose sharply for the reconfigured group at E1 ($p < 0.0001$), reflecting the increased need to clarify the new roles and tasks of the team members at the shift. At the subsequent session (E2) the number of clarifications fell back to a level comparable with the control and cross-trained groups.

3.2.6. Summary of process measures: In terms of some of the process measures of team performance (i.e. time of contacts in danger zone, number of utterances per contact, and number of clarifications during strategy sessions), the following observation can be made: the reconfigured group displayed an immediate and substantial performance decline at the time of reconfiguration (i.e. E1) and this

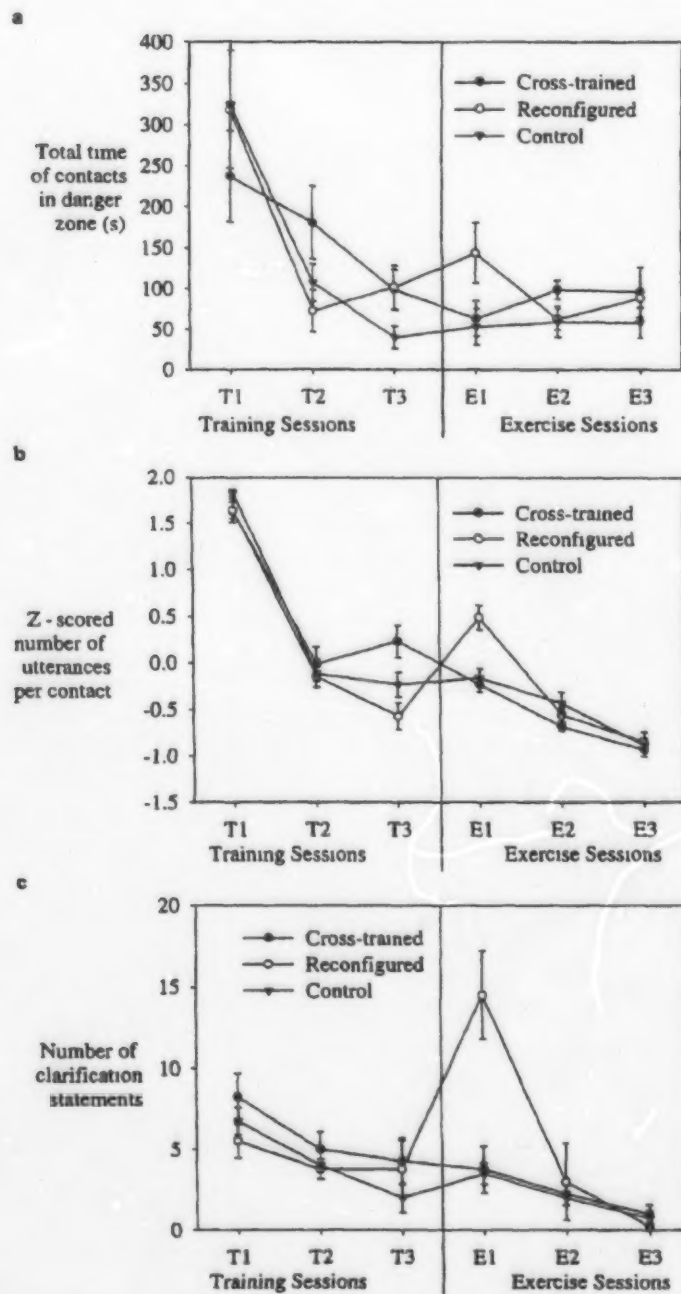


Figure 3. Process measures: (a) the total time that any contact is in the danger zone; (b) the Z-scored number of utterances per contact, (c) the number of clarification statements in the strategy sessions.

decrement rendered performance significantly *poorer* than that of teams in the cross-trained condition.

4. General discussion

The present paper had two objectives concerning team performance. The primary objective was to examine the utility of experiential cross-training in a team context on team decision-making under conditions of time pressure. The secondary objective was to assess the potential benefit of experiential cross-training in a team context when teams undergo a reconfiguration. These issues are now addressed in turn.

4.1. *Experiential cross-training and the effects of time pressure*

Hypothesis 1 asserted that experiential cross-training would result in better performance in the time-pressured scenario because it would foster and enhance development of the Team Interaction Mental Model. This hypothesis was not supported. Specifically, the cross-trained group did not out-perform the control group on any of the process measures and, in fact, displayed slower speed of decision-making throughout the time-pressured exercise scenario.

Previous studies have demonstrated the benefits of cross-training, especially in situations of high workload (Schaafstal and Bots 1997, Cannon-Bowers *et al.* 1998). However, these studies employed less intense cross-training than the present one (e.g. training through written descriptions of other team members' tasks) and the training manipulation was delivered outside of the experimental scenario. In contrast, in the present study, cross-training was more extensive and formed an integral part of the experimental design. Accordingly, the present study permitted an assessment of the relative impact of training methodologies, given a fixed time period for training.

From the perspective of the multiple mental models' conceptualization of Cannon-Bowers *et al.* (1993), we speculate that the cross-training group may have indeed achieved superior Team Interaction Model skills, but these may have come at the expense of poorer Task Model and Equipment Model levels that were, perhaps, equally pertinent in the present time-pressured scenario. Conversely, the high degree of task-specific expertise acquired during training in the control condition may have been sufficient to override any deficiencies at the Team Interaction Model level. Is experiential cross-training without merit? The answer is clearly no, as evidenced by the resiliency of teams trained in this manner to team member reconfiguration.

4.2. *Experiential cross-training and the effects of reconfiguration*

The immediate effect of reconfiguration was clearly negative in all aspects of team performance. Compared to the control condition, both outcome and process measures of performance in the reconfigured group degraded substantially between the third session of the training (T3) and the first session of the exercise (E1). Although most performance measures for the reconfigured teams did return to the levels of the control group following E1, processing speed for the reconfigured teams never recovered to the level of the control. Thus it seems that certain aspects of team performance do not recover easily from reconfiguration and it is an empirical question whether they ever recover in the longer term.

Previous cross-training studies (Volpe *et al.* 1996, Schaafstal and Bots 1997, Cannon-Bowers *et al.* 1998) have employed training methods such as knowledge provision, instruction in the characteristics of other team member positions and individual exposure to other members' positions. As mentioned, this degree of

training was also given to the reconfigured group (and indeed to all groups) in the familiarization phase of this study. The present results specifically suggest that this level of cross-training may be insufficient to fully ameliorate the effect of reconfiguration. The experiential cross-training manipulation employed in the present study (i.e. the cross-training condition), in contrast, resulted in no performance decrement upon team member reconfiguration at E1.

Could there be a *relative* utility of our experiential cross-training methodology for compensating for the effects of reconfiguration? For the outcome measures of team performance there was, in fact, no benefit: speed and accuracy were no worse for the reconfigured group than for the cross-trained group at E1. However, a somewhat different perspective on the benefits of cross-training emerges from a consideration of the process measures of team performance. In contrast to the cross-trained group, the reconfigured group required more overt communication and clarification of the task during strategy sessions to cope with the reconfiguration; and they devoted fewer attentional resources during the first session of the exercise condition (E1) to contacts in the danger zone around the ship. This then raises an important consideration. In operational contexts, communication facilities may be restricted or even unavailable, precluding team members from using this important compensatory mechanism for ameliorating the effects of reconfiguration. In this case, the performance cost associated with not cross-training may be higher than when team members could communicate their new strategies freely with each other.

In real military situations, teams may need to be reconfigured for a variety of reasons, most of which would involve the loss of a team member. In the present study, team member reconfiguration was operationalized by holding the team membership fixed, and simply shifting the members to new positions. Although admittedly unlikely in a military setting, this operationalization falls far short of a worst case scenario, where new members are brought into the team and existing members must undertake less familiar roles. Hence, although the present findings are preliminary and thus should be interpreted with caution, the authors believe that they in fact highlight a need for further research on reconfiguration and clearly demonstrate the benefit of experiential cross-training in a team context.

The decision concerning the degree of cross-training must be based on the anticipated operational situation. For if there is no expectation of reconfiguration, there may be a cost associated with this level of cross-training in the sense of loss of individual member expertise. If, however, reconfiguration is expected and it is unlikely that there will be an opportunity for the reconfigured team to discuss the adjustment of their strategy, then cross-training in a team context may be desirable. This research addresses a critical issue for trainers who typically have limited training time and resources available: specifically, the delicate balance between the benefit to be gained from cross-training and the cost associated with not devoting sufficient time to developing individual level expertise within the team context.

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Appendix: categorization scheme for coding statements obtained from videotaped data

PS-Strategy statements concerning the next contact to be processed or for determining and inputting the classification of a contact within a category;

TA-Statements concerning the assignment of tasks to individual team members;

SEQ-Statements concerning the order in which information is offered or decisions are made;

COMM-Statements concerning the content and timing of communications between team members;

CLAR-Statements involving clarification of the task (e.g. going over what information must be given to each team member);

RES-Restatement of previous strategies;

REC-Statements concerning strategies for the recording of interim information on paper;

MISC-Statements on strategies unique to the team or where the strategy was unclear;

NS-Statements that were not strategies.

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